Designing and Implementing a Hands-On Labs for an Introductory Robotics Course: A Case Study in Directed Constructionism

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1 Introduction
In 1998, Carnegie Mellon introduced a new introductory robotics course titled General Robotics. It was lecture based, and weekly assignments were given in which students programmed simulations of particular robot tasks. The course included an optional project component where students (in teams) could define and carry out an independent project. About half the class undertook projects while the remaining students opted for the alternative of writing a series of reports. Of those who decided against the projects, many were afraid of being overwhelmed because of a lack of project experience prior to the course. Those who did undertake the projects gained valuable experience, but what they learned did not necessarily promote the curricular goal of the course. The main goal was to give a broad introduction to robotics in order to prepare for more advanced course work.

Before the semester had ended, we (Howie Choset, the instructor, and students in the course) had already begun asking ourselves a number of questions about the design of the course. How can we extend this hands-on component to all students who enroll in this course? How can we do it in a way that closely parallels the carefully chosen curriculum of the course? We attempted to answer these questions by setting out to design an improved version of the course. This new version of the course was offered in the Fall of 1999.

In the process of answering these questions we contrasted the instruction-based approach employed in the first offering of the course with the ideas of constructionism, a very hands-on individual approach to education. In doing so, we learned a lot about learning, and identified our biggest challenge: how do we meld the ideas of constructionism with the traditional institutional constraints of curriculum, class size, and limited resources. To answer this challenge, we assembled a guiding list of issues to be considered when applying constructionist ideas to existing curriculum. We call this approach directed constructionism, a hybrid of instructional and constructional education.

This paper is divided into three sections. The first section gives a brief description of the strengths and shortcomings of both instructional based education and the constructionist approach, and our ideas on how to fit the two approaches into one complimentary structure. The second section gives insight into the short history of the General Robotics course, and its place in the university's Undergraduate Robotics Minor. It goes on to explain how we applied our ideas to the redesign of this course. The third section is an initial evaluation of this redesign, based primarily on feedback regarding its current implementation.
2 Background

2.1 Instructional Education
The instructional model of education is quite entrenched. Students sit in lecture halls or classrooms and are taught by the professor in front of them. The word "taught" casts the educator as the actuator of this knowledge transfer. This flow of knowledge is largely unidirectional with the exception of occasional questions and discussion. The amount of questions and discussion is usually inversely proportional to the class size, resulting in large classes often becoming the academic analog of watching an informational video. Of course you can learn some key facts about Italy from a travel show, but to know what Italy smells like, you have to go yourself. Large classes do not "go to Italy" because it is far away, expensive, and difficult to take a large group anywhere.

The instructional model of education is often subject to these constraints because of its large-enrollment and limited-resources format, but it serves another purpose well: guaranteed curriculum. Often courses are taken in a sequence where early courses prepare students for more in-depth study in advanced courses. Each individual course has a place in this curriculum hierarchy, the end goal of which is to prepare a student to transcend to the next level (i.e. going to college, beginning a career, etc). This assigns each course a responsibility to equip its students with the certain knowledge, skills or understanding required for the next course in the sequence. The instructional model caters well to this, creating a clean and concise structuring. Despite this convenience of structuring the information, instruction-based education methods leave us wondering if the students have really connected with the knowledge --- do they really learn what Italy "smells" like?

2.2 Constructionist Approach
The constructionist approach to education is highly immersive. It was formally outlined in 1991 by educational researcher Seymour Papert and its core ideas stem back to the educational theories of his mentor, Jean Piaget. "Constructionism is an active learning process in which students construct things that are personally meaningful to themselves or others around them." Instead of being served information in the traditional one-way, instructional setting, students develop their own knowledge and understandings of a subject through physical construction and implementation of their ideas. Often many things go wrong, resulting in a very messy process of discovery. This is an irreplaceable strength of the approach. Constructionism places the action in the hands of the student and the learning becomes motivated by their interests.

In format, constructionist learning is usually self-paced. Skills and knowledge are often sought out on an as-needed basis. The learning is very individual and personal, although it does not exclude collaborations. Students engage in self-defined projects co-linear with their interests. The instructor takes on a mentoring role, offering guidance or advice when helpful. This requires an instructor/mentor to allocate a good deal of individual attention to each student, and thus does necessitate small class sizes.

While constructionism is a very natural approach to learning, it is not, in its pure form, compatible with the constraints often faced in higher education, particularly class size and curriculum. When dealing with a large class, it is difficult to address the needs of individual students that arise from a self-paced learning format. Furthermore, it is difficult to replace the instructional model with student-defined projects and still ensure that all the
students are learning a standard curriculum that will be expected of them in more advanced courses.

2.3 Directed Constructionism
In our General Robotics course, we have made our first attempt at developing a hybrid approach termed directed constructionism. Directed constructionism strives to bring harmony to the elements of the two approaches that are at odds by supplementing existing instructional-based curriculum with a constructionist component. Ideas are presented in an instructional setting, but in parallel, students are given the opportunity to expand on these ideas through related projects. This approach goes beyond existing hands-on environments (i.e. lab courses) in that it allows creative freedom, presents assignments as design challenges, and attempts to make assignments personally meaningful.

However, the directed constructionism approach also places a number of new responsibilities and challenges on the educator. In this project-based course model, the main concern becomes how to elegantly integrate the constructionist approach while continuing to serve the goals of the curriculum and remaining feasible given the constraints of class size and available resources. This raises many questions about issues that were not present in the previous instructional model, yet are central to the successful implementation of this new course. To identify some of these issues we constructed the following working list. This list served as a design template for the new course, and has now become our benchmark for evaluation.

Goals of Directed Constructionism Design
• Develop an artifact construction component to the course.
• Provide ample tools, both physical ones and ideas. In both cases, do not simply give minimum ingredients for a recipe, but enough to do a task many ways. (In the case of providing ideas, this is largely the job of instructional component.)
• The hands-on component should be closely tied with theoretical ideas in the curriculum.
• Challenges should be personally meaningful to students. Not toy tasks, but realistic, creative design challenges.
• Give freedom to explore, but remain within constraints of time allotted per subject including assignment time per-week, and relation to curriculum goals.
• Make sure that there is a creative component where students can define their own path to a stated goal thus encouraging design diversity.
• The creative space does not necessarily have to include the goal task, but should facilitate reaching it.
• Present the assignments as goal-oriented design challenges.
• Do not give linear instructions.
• Present labs through medium that will facilitate easy access to useful information.
• Give startup information and a well-defined end specification.
• Develop a grading scheme that is fair, well defined and friendly to large enrollment numbers.

2.4 Why Robotics?
The real reason why we did this in a robotics class is that we are roboticists trying to teach robotics. However, robotics education provides an ideal setting in which to test this new educational approach because of its flexibility. Unlike traditional fields, robotics is still an
emerging area. Relatively few programs exist at the graduate level, and even fewer exist at the undergraduate level. The courses in existence are still new and are open to rapid change and new approaches. Course goals can change from year to year as new technologies and theories are introduced into the field at large.

Robotics education is also a good fit for Directed Constructionism because of its physical nature. Many of the ideas introduced in a robotics course (through reading or lecture) can be physically implemented as a mechatronic system. The design space of mechatronic systems is immense allowing opportunity for rich variation in designs for a specific end goal. Also, creating these systems requires skills from various disciplines (mechanical engineering, electrical engineering, computer science, and more). This interdisciplinary nature in fact suggests the constructionist approach, in which students with specialized skills can gain knowledge from those with different backgrounds by working together through a creative design process.

3 Applying Directed Constructionism to the General Robotics Course
We began to apply these new ideas in the second offering of General Robotics, during the Fall 1999 semester. Other than minor changes in the schedule, the instructional (lecture) component of the course remained largely unchanged. Where this offering differed from the first offering of the course was the elimination of self-defined projects and the addition of a lab component that would follow the established curriculum (see Appendix A for syllabus). From the design perspective this meant developing and authoring eight separate lab assignments, and researching and assembling lab kits that allowed for these labs to be executed. From a logistics perspective this meant securing funding for the equipment, obtaining lab space, training a small staff of teaching assistants, and preparing supporting lab materials such as test environments for the robots to operate on. This section begins by discussing the course’s demographics which helped set up the criteria for our educational design. It then moves on to the actual details of creating and assigning these new labs, and the thinking behind the compilation of the kits students used to realize the assignments.

3.1 Course Demographics
The diversity of students’ class status and backgrounds, as seen in the 1998 course offering, was a guiding consideration to how we would apply the new course model to the 1999 offering. The course is open to all students in the university, but requires students to have had introductory C programming and calculus. However, the overwhelming majority of students enrolled were from mechanical engineering, electrical and computer engineering, and computer science. It is intended for a junior level, but enrolled approximately 30% sophomores and 20% seniors. Female enrollment was about 18%. Prior experience levels had ranged from sophomores just learning basic robotic concepts to seniors who had already spent 3 or 4 years working in research robotics labs at the university. There were approximately 70 students in the 1998 offering. (Note: These demographics remained relatively unchanged in 1999.) The design challenge to us thus became to develop labs that would engage students with varied levels of experience, and draw on students’ different backgrounds.

3.2 Creating and Assigning the Labs
With an understanding of our audience we set about creating the actual lab assignments. We began by identifying which curriculum topics were most important and best suited for
lab implementation. After topics were identified, we began the imaginative process of designing tasks that would allow for creativity while requiring that an understanding of the topic at hand be reached. Here is where we closely referred to our list of Directed Construction design goals (above). A list and brief description of the lab assignments is given in Appendix B.

Concurrent to designing the assignments, we made logistical decisions to divide the class into lab groups of three students each, and assign labs to be done out-of-class. To accommodate these out-of-class assignments, we would provide a staffed laboratory equipped with computers and tools, and each group would be lent a complete robot building kit for the entire semester.

Lab assignments would be presented to students on the web. This medium was chosen for its ease to update and post information and convenience in providing references to extra information and help topics which often referenced external resources. Since all the assignments would require robots to be programmed on a computer, the web based format would allow students instant access to this information.

In terms of format, each lab included the following:

- Introduction: subject, educational goals, background info.
- Challenge statement: very general, i.e. “Build a robot (creature) that chases light.”
- Evaluation: specific criteria and demo/testing procedure. This often discussed the parameters of a test environment for the robot (i.e. a table with guides drawn on it)
- Grading: actual scores corresponding to degree of success in achieving criteria stated in evaluation tips
- Things to think about: help information, and related subjects of interest, additional readings

Special consideration was given to the amount of information and help provided to the students in each lab assignment. Each lab had a pedagogical focus congruent to the curriculum, and we aimed to keep time consuming aspects of a project which were outside of this focus to a minimum by providing help tips and in some cases sample designs for a particular subsystem. This explored a delicate balance: if too much information was provided, students creativity might be constrained; if given too little, peripheral aspects might detract from the focus of the assignment, and furthermore may exceed the target weekly assignment time for an individual class. Designing this balance has been one of the most challenging aspects of developing these assignments, and we expect it to be the most evolving aspect as assignments are improved from year to year.

Example: Provided shoulder joint design in robot arm kinematics lab
One lab explores robot arm kinematics, and requires students to construct a 2 degree of freedom jointed planar arm (shoulder and elbow joints). The arm they build will serve as a platform on which they will test forward and inverse kinematics algorithms. Understanding kinematics is the pedagogical focus of the assignment. To aid in the construction of the arm, we provided a sample design for a shoulder joint with sensor feedback. Students could opt to use this design or develop their own. We felt that in this case, it saves students from a potentially time consuming aspect, yet does not constrain creativity as the rest of the arm (including the elbow joint) required independent design and construction.
3.3 Lab Kit Design
With an outline of what the lab assignments would be, we set out in search of materials that would enable students to attack these assignments. A paramount consideration was that the kits had to be ample enough to allow for an assignment to be accomplished in a variety of creative ways. Additionally, kits had to be cost effective, rugged enough to last for years, serviceable, and provide for easy startup while not abstracting important pedagogical aspects. What we arrived at was Lego (including motors) as a hardware component, the Handy Board (Motorola 68HC11 based) microcontroller board for control, and our own selection of assorted sensors and other components. In total, each kit cost about $600. Brief notes on each decision follow.

Lego as a prototyping tool
Lego, over the past two decades, has evolved from a children’s toy to a fully capable engineering systems prototyping tool. In addition to its well-known structural components, it offers gears, motors, wheels, sensors, and even programmable micro-controllers. It is cheap (relative to other prototyping tools), familiar, allows for very rapid construction, and is readily available.

The MIT Handy Board micro-controller
The Handy Board was designed by Media Lab research scientist, Fred Martin, and is intended for student robot projects. It has built in batteries, interfaces directly to motors and sensors, has a LCD text display, and a very easy to learn C-programming environment. Lego offers a less expensive alternative, their RCX micro-controller, but the RCX is more limited in I/O capability making it not well suited for some of our assignments.

General Robotics sensors and miscellaneous electronics
We supplemented the Lego and Handy Board kits with our own selection of electronic parts from various electronic supply companies. In many cases parts were included with a specific purpose in mind (i.e. photo-resistors for a light-seeking robot assignment). In some cases, however, parts were found in surplus catalogs and were included because of low cost and creative potential (i.e. rolling ball inclinometers).

4 Evaluation
The primary means of measuring our success in implementing the directed constructionism approach is to assess how we answered the specific challenges we foresaw (listed in 2.3) and respond to those that were unanticipated. From the student's standpoint, response was overwhelmingly positive. They enjoyed the Lego labs and the designs they produced varied immensely. The following sections discuss how well integrated the labs were with the lectures, our grading criteria, and the unexpected side effect of lab and course culture.

4.1 Lecture-Lab Integration
A primary design goal for the new lab component was to ensure that they related to the curriculum introduced in lecture. This is central to the success of the directed constructionism approach. It is visible from the syllabus and the lab descriptions in the appendix that most of the assignments corresponded to the lectures, however, some lab assignments represented the theories better than others. In one particular case, the lecture
was focusing on Ackerman steering theory\textsuperscript{1} and the assignment was to build a robot that could escape a parallel parking scenario. While the assignment related to the theory, it was not clear that the theory could be applied to the problem to gain advantage in implementation. One student pointed this out to us in an email:

“We are confused about this lab... Right now it seems as if this lab is very disjointed, where we haven't learned anything to help us with this and all that seems feasible is trial and error. I tried looking at the book and couldn't find answers there. Will anything relative to this lab be covered in lecture tomorrow?"

This email is a good representation of the willingness of the students to provide feedback regarding our ideas. In a similar situation, feedback on the first part (forward kinematics) of the two week kinematics/robot arm lab lead us to alter the second part (inverse kinematics) portion to provide more interest for the students. While they recognized the usefulness of an arm, several students expressed that targeting a x-y coordinate was very mundane, so based on this feedback, we added a criteria for the second week demonstration - pick any shape and have the arm draw it. Students had their arms draw a simple circle, stars, and even a fish. The in-line change to the lab reinforced the presence one of the basic ideas of constructionism: the importance of being responsive and willing to change.

Some labs intentionally diverged from the lecture schedule and became standalone curricula. These cases represented points in the curriculum when the theories presented in lecture did not have physical analogies that could be implemented in lab and also when a particular curricula was better explored in lab without theoretical supplement. One particular example of this divergence was the Mars-Rover lab (which served as an in-class contest).

In the Mars Rover lab students were assigned the task of designing and building a robotic rover to explore an “extraterrestrial surface” via tele-operation. They were given only "satellite images" of a surface, which was constructed out of styrafoam to include obstacles such as small stones, large cliffs, and a ravine. Students were also given topographical maps with specified landing and goal zones. The design challenge was to construct a rover to get from the landing zone to goal zone. The robot would be operated from a computer terminal in a separate room while viewing progress through a video camera.

The goal of this assignment was to learn about robot tele-operation, explore different types of locomotion, and participate in a simulated space robotics scenario. This assignment did not relate to the topics being discussed in lecture at the time, but it did allow the students to work on a more significant project. Many responded that this was the most fulfilling project of the entire course.

This two-week assignment/contest was so well received by the students and proved to be such a great learning experience, that we have decided that next year, we will suspend standard lectures during the contest. Instead, we’ll use this time to meet with individual groups about their designs. This will help foster the design experience component of the class.

\textsuperscript{1} Ackerman steering is the type of steering found on normal automobiles where the front wheels steer and the rear wheels remain fixed.
Parallel to the lecture-related vs. non-related assignments disparity was a variance in creative freedom, with the non-related labs being the more open ended. This relationship between relevance to lecture and creative freedom is something that we are continuing to gauge. While assignments like the Mars Rover lab have proven to be an excellent experience for students, other labs, like the path planning and motion lab, which directly reflected content taught during the lectures, allow for better control over what students learn. We believe that both types of assignments are very important to the course. Students appreciated both types of assignments, but recognized that even the more constrained lecture-related assignments allowed for more creativity than many of their past lab experiences:

“The way to differentiate these labs from the labs that students typically do in engineering courses is that there wasn’t a list of numbered instructions handed out to students giving a linear path from point A to point B. Students had to figure most of it out for themselves, which teaches them a lot more than simply developing their abilities to read and following instructions. I’m pretty sure that was thoroughly perfected back in first grade. The labs allowed for creative freedom, while also achieving the goals of the curriculum.”

4.2 Grading
Evaluating and assigning grades to student projects was one of the most difficult issues we encountered, and it is not a fully resolved issue. Based on the size of the class and the president set by engineering classes to grade objectively, our first intention was to evaluate students solely based on project success. Students questioned why, when we encouraged a creative process, did we grade solely on end functionality. They suggested if a group had a unique design, it should be taken into account while assessing their accomplishments. This question exposes one of the most serious dilemmas of directed constructionism how do we evaluate different paths toward the same goal? How do we encourage creativity without detracting from the importance of producing working results? We approached this on a case-by-case basis. While functionality was always the official criteria for evaluation success, we made accounts for exceptional designs if they did not completely accomplish the goal task.

4.3 The Lab Culture
The lab component also had unanticipated side effects that strengthened our belief in the directed constructionist approach. The long hours spent in the lab and intensity of the assignments brought a unique sense of community to the course. Another result was an emergent collaborative learning environment. Groups actually intermingled and helped each other construct new and unique designs. Discussions with members of other teams often solved problems and sprouted new ideas.

5 Conclusion
By applying directed constructionism to robotics education, we feel we have created a learning experience that has allowed students to develop an improved understanding of material covered over past approaches. This was accomplished through the integration of goal-oriented lab assignments and a traditional lecture-based curriculum. In addition to acquiring an understanding of the material, students participated in a multidisciplinary design experience that was unique to this course. The combination of applying theory to practical-hands on tasks and working across disciplines resulted in an engaging learning experience for both the students and the faculty.
Teaching the course was a challenge that kept us constantly on our toes. Although labs paralleled the lecture in topic (excepting the Mars Rover lab mentioned in section 4.1), Professor Choset made a conscious effort in lectures to use lab work as practical analogy for the theory being presented. Likewise, lab assistants made frequent mention to the theories being presented in lecture to answer a practical question during lab hours. This synchronicity strengthened the connection between theory and practice, but required additional planning for course faculty and staff including weekly meetings (sometimes more often). Another challenging teaching aspect was every group attacked each lab differently. This required lab assistants to learn a particular group’s methods before being able to offer help. This required lab assistants to be knowledgeable in all disciplines being applied and also have a strong intuitive understanding of the task – an understanding that usually only develops from lots of experience.

Grading remains an unsolved issue. Grading solely on performance serves a number of purposes. It accommodates the large number of students in the course, provides an objective standard for evaluation, and reinforces the importance of producing working results. Conversely, it discourages creativity, and often does not reflect the amount of effort that has gone into an assignment where 90% of the robot works, but a minimal 10% prevents it from accomplishing the task. In cases such as these, the current grading criteria does not take into account the 90% functionality, and a poor grade becomes negative reinforcement of what in many cases were still 10-15 hour efforts. We are currently considering a number of hybrid design-review/performance grading schemes.

We are currently planning the Fall 2000 semester version of the course. The updated schedule will drop one lab assignment (the Akerman steering lab) and add a sensor based motion planning lab. We will also allocate more time and emphasis to the Mars Rover lab since it proved to be such an engaging and exciting experience for the students. One notable change is that the course will limit enrollment to 50 students and there will be 10 teaching assistants (all of which had the course in 1999). We expect this improved ratio (1999 had 75 students and 2 assistants) and our slightly groomed schedule will allow the course to run very smoothly in Fall 2000.

Looking further ahead into the future, we will seek to improve the course and directed constructionism concept on a number of fronts. The Mars Rover lab was unique to the others in that it provided an exciting and imaginative scenario. It was clear that the class became really excited by this aspect. Exploring how such scenarios can be extended to other lab assignments is a potential topic for future investigation. To facilitate such scenarios, it is within the scope that supporting technologies and devices be developed (i.e. a remote video camera tripod for the Mars Landing). Beyond the borders of this course, we will seek to explore how directed constructionism can be extended to other academic subjects, and extended to the secondary and elementary levels of education as well.

Appendix A: General Robotics Syllabus

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<thead>
<tr>
<th>Week</th>
<th>Topics</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Robotics Overview, Vision</td>
<td>written homework</td>
</tr>
<tr>
<td>2</td>
<td>Vision</td>
<td>Lab 1: Vision on Sun workstations</td>
</tr>
<tr>
<td>Assignment</td>
<td>Description</td>
<td>Curriculum Aspect</td>
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<tr>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
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<tr>
<td>Lab 1: Vision on Sun work Stations</td>
<td>Take an image file and write a program to: threshold, histogram, and detect edges.</td>
<td>• Robot Vision Algorithms</td>
</tr>
</tbody>
</table>
| Lab 2: Behavior Based Robots | Build and program a robot that will drive to a light source in a test environment. | • Behavioral AI  
• Learn to use robot building kits.                                                  |
| Lab 3.1: Motion Planning  | Build a robot base that can translate and rotate accurately                   | • Understand robot base mechanics  
• Understand necessary hardware functionality for certain motion planning algorithms |
| Lab 3.2: Motion Planning  | Implement the wave front motion planning algorithm on the mobile base, such that the base will plan a path through 4’ x 8’ world given a numerical map of obstacle locations | • Motion planning algorithms                                                       |
| Lab 4: Ackerman Steering  | Build a robot base that uses an Ackerman steering configuration and program it to escape a “parallel” | • Ackerman Steering and alternative drive configurations  |

Appendix B: Descriptions of Lab Assignments
| Lab 5: Mars Rover | Build a tele-operated rover to navigate some ridiculously challenging terran you’ve only seen in low quality digital photographs. Navigate your robot from an approximately known start to finish via text based computer terminal control while watching progress through a small video screen with a bad camera angle. | • Robot Locomotion  
• Space Robotics Design  
• Design and programming for tele-operation |
| Lab 6: Forward Kinematics | Build a 2 DOF planar jointed robot arm, and program it to plot points (with a pen attached as an end-effector) described by a table of theta1 and theta2 coordinates corresponding to shoulder and elbow angles. | • Forward Kinematics  
• Robot Arm Mechanics |
| Lab 7: Inverse Kinematics | Implement a software function that takes an x-y coordinate and drives the arm to that point. Then have the arm draw a picture of a shape you have chosen. | • Inverse Kinematics |

**Bibliography**

1. Resnick, M. *Turtles, Termites, and Traffic Jams*, (pp. 24-27)  

**Michael Rosenblatt**  
Michael will be a senior at Carnegie Mellon University in Pittsburgh, PA, where he studies "Intelligent Media" (a student-defined major). He has worked in research robotics labs at both Colorado School of Mines and Carnegie Mellon. Over the past year, he has worked closely with Dr. Howie Choset to design and implement a hands-on supplement to Professor Choset’s introductory robotics course. This course was taught for the first time in the fall of 1999, and Michael was the teaching assistant for the course. He is very interested in new technologies for toys and learning and will be spending his second summer working in this field with the Epistemology and Learning Group at the Massachusetts Institute of Technology, Media Laboratory.
Howie Choset
Howie is an Assistant Professor of Mechanical Engineering and Robotics at Carnegie Mellon University where he conducts research in motion planning and design of serpentine mechanisms, coverage path planning for de-mining and painting, mobile robot sensor based exploration of unknown spaces, distributed manipulation with macroscopic arrays, and education with robotics. In 1997, the National Science Foundation awarded Professor Choset its Career Award to continue the work in the underlying fundamentals of roadmaps for arbitrarily shaped objects; the long-term goal of this work is to define roadmaps for highly articulated robots. Recently, the Office of Naval Research started supporting Professor Choset through its Young Investigator Program to develop strategies to search for land and sea mines and to construct a land-mine-search robot. Professor Choset co-chairs the IEEE Technical Committee on Mobile Robots with Xiaoping Yun and co-chairs the SPIE Mobile Robots Conference each year with Doug Gage. In 1999, he is co-chaired with Dr. John Bares the 1999 Field and Service Robotics conference and co-organized with Professor Karl Bohringer a workshop on distributed manipulation; currently, Professors Bohringer and Choset are editing a book on the subject. Finally, Professor Choset directs the Undergraduate Robotics Minor at Carnegie Mellon and teaches an overview course on Robotics. Recently, he developed a series of Lego Labs to complement the lecture portion of the course which were implemented this past fall.

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Amy is a sophomore in Electrical and Computer Engineering at Carnegie Mellon University. She is minoring in Robotics, and was a student of General Robotics in the fall of 1999. She will be a teaching assistant for the course in the fall of 2000.

Rahul Bargava
Rahul is a graduating senior in Electrical and Computer Engineering at Carnegie Mellon University. He is minoring in Robotics, and was a student of General Robotics in the fall of 1999. Rahul was the teaching assistant for another undergraduate robotics course, “Mobile Robot Programming.”